ON THE EFFECT OF MERCURY VAPOUR ON THE CONTINUOUS SPECTRUM OF HYDROGEN EXCITED BY CANAL RAYS OF HYDROGEN*

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Plate II

ABSTRACT. It is shown that the presence of Mercury vapour in the discharge tube brings about a marked change in the relative intensity distribution of the continuous spectrum of Hydrogen, as excited by canal rays of hydrogen, in the observation chamber of a canal ray tube in its simple form. The effect is found to be more pronounced at higher operating voltages than at low. The bearing of this result on the known observations on the excitation of the continuous spectrum by canal rays is pointed out ; finally there is given a discussion of the possible explanations for the change brought about by the presence of mercury vapour.

INTRODUCTION

§ 1. There is a certain amount of evidence† to show that the continuous spectrum of Hydrogen, observed with the canal rays of Hydrogen, is in main identical with that obtained in the Geissler tube and is due to the excitation of the stationary molecules of Hydrogen by impact with the canal ray particles. The origin of the continuous spectrum in the Geissler tube has been generally ascribed to H_2 and according to the theory of Winans and Stueckelberg[1] is emitted as a result of a transition between the $1s\sigma$, $2s\sigma$: $^3\Sigma_u$ and $1s\sigma$, $2p\sigma$: $^3\Sigma_u$ states of the molecule. There appears to be a small but definite difference in the relative intensity distribution of the continuous spectrum as obtained with the canal rays and in the Geissler tube. The intensity in the region $\lambda 2500$Å in the case of the latter is much more accentuated than in the former. Another important finding† in the same connection is that this intensity distribution is independent of the energy of the exciting canal rays. The effect of Mercury vapour on the intensity distribution of the continuous spectrum obtained with the canal rays possesses a certain amount of interest on account of the fact that it is the foreign gas most likely to

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† *Vide* : A paper by the author "On the continuous spectrum of Hydrogen as excited by canal rays of Hydrogen" published elsewhere. This will be referred to as (I) in this paper.

be present in the discharge space at the low pressures that obtain in the canal ray tube, unless specific precautions are taken to eliminate it. There is, therefore, the possibility that many of the apparently contradictory results obtained by different workers may in fact be due to the difference in the efficiencies of the experimental arrangements in preventing the diffusion of Mercury vapour into the discharge space. To quote a specific example, it is still obscure under what conditions the continuous spectrum in the canal rays observed by Stark [2] is obtained. It is, therefore, necessary to know the nature and the order of magnitude of the alterations produced in the intensity distribution of the continuous spectrum of Hydrogen by the presence of Mercury vapour for a satisfactory elucidation of the results obtained on its intensity distribution. The resonance line $\lambda 2537$ of the Mercury atom has got an excitation energy which nearly equals the dissociation energy of the Hydrogen molecule ; so that on general grounds we expect a weakening of the continuous spectrum as a whole relative to the Balmer lines as a result of the admixture with Mercury vapour. The minimum excitation potential of the continuous spectrum has been determined by Finkeinburg and Weizel [3] as 11.84 and the maximum as 13.8 volts. The excitation function of the continuum is, therefore, very narrow and sharply defined. The ionisation potential of Mercury atom[4] being less than this, the possibility of a change in the intensity distribution on account of collisions of the second kind is not probable. This does not, however, exclude the possibility of collisions of this type, involving Mercury atoms in stages of ionisation, higher than the second. An interaction involving molecules of Mercury [5] may be practically excluded both on account of the smaller available energy and the low probability for their occurrence at the pressures that obtain in the canal ray tube. It is well known that remarkable changes occur in the spectra of both atoms and molecules in the presence of foreign gases, resulting sometimes either in a general enhancement or reduction of intensity among lines and bands and sometimes in the production of lines and bands which under ordinary conditions are either absent or very weak. That fundamental changes in the intensity distribution of the continuous spectrum, obtained as a result of the addition of a foreign gas, are shown in a remarkable manner by the experiments of Smith.[6]

In these experiments, I have adopted the same plan of investigation as reported in (I). A study was made of the variation in the relative intensity distribution of the continuous spectrum, in the presence of Mercury vapour, with the energy of the exciting canal rays ; it was this aspect of the problem that had an immediate and a direct interest for the investigations described in (I).

EXPERIMENTAL

§2. The experimental arrangement used for this investigation is the same as that described in (I) except for the discharge tube and the connections in its neighbourhood. It was not necessary here, to have the elaborate system of liquid-air traps used in (I). For the sake of completeness, a brief description may be given of the experimental arrangement. The discharge tube was 3.5 cms. in diameter, with a cathode of moulded Aluminium 2.0 cms. in length provided with a canal 0.2 cms. in diameter. The anode which was of Aluminium was fixed in a side tube at a distance of about 16 cms. from the Cathode. Evacuation was obtained by means of a set of Mercury diffusion pumps of the Waran type backed by a Cenco Hyvac Oil pump. Liquid-air traps were used for preventing the diffusion of Mercury vapour from the pumps and manometers into the discharge tube. The gas Hydrogen was obtained electrolytically and was purified by passing over heated Magnesium and Copper filings. The method of gas-streaming was used. The H. T. was a half-wave rectified D. C. obtained from a transformer coupled with a Kenetron circuit. The anode was connected to the H. T., the cathode being earthed through a milliammeter. The spectra were taken with a small Hilger Quartz spectrograph, a cylindrical lens being used for focussing the image of the canal rays on the slit of the spectrograph. The observations given below were taken. A select number of these spectra were run on a recording Zeiss micro-photometer; the more important of the micro-photometer curves are shown in figs. (2-5).

For the purposes of the present investigation, it was not necessary to follow the absolute intensity distribution in the continuous spectra obtained under the different conditions. It was sufficient if differences in the relative intensities could be distinguished at any given point on the spectrum (compare : Finkelnburg[7]). So long, therefore, as the exposures were within the limit of saturation of the plate, which condition was kept true in these experiments, the density at any point became a measure of the intensity.

The experimental observations are the following : On Pl. 4, canal ray spectra were taken with canal ray energy of 4, 6, 8, 10 kV. respectively with a discharge current of 2.0 m.a. and a time of exposure of 2.5 hours. On Pl. 6, the first four observations give the canal ray spectra, for energies 4, 2, 8, 6 kV. with times of exposure of 3, 4, 2.5, 3.5 hours respectively with a discharge current of 2.0 m.a. The sixth observation again is a canal ray spectrum obtained with 1.0 kV. across the discharge tube and a time of exposure of 5 hours for a discharge current of 2.0 m.a. Observations 5, 7, 8, 9 give the Geissler tube spectra obtained under the same conditions (*cf.* I) for a discharge voltage of 1.0 kV. and a current of 0.5 m.a. with times of exposure of 0.5, 1, 2, 3 minutes respectively. Pl. 8 depicts the canal ray spectrum for operating voltages of 3, 2, 1.3 kV., with a discharge current of 2.0 m.a. exposed for 4, 4, 1/3 hours respectively.

RESULTS AND DISCUSSION

§3. *Results and Discussion.* In the spectra given herewith, the general absorption (due variously to the material of the spectrograph, air, the photographic emulsion) begins at about $\lambda 2300 Å$. The intensity distribution in the micro-photometer plates can be considered to be reliable only up to this limit. The diminution in the intensity of the continuous spectrum as a whole is well demonstrated by the order of magnitude of the times of exposure required for obtaining the spectra in the case of Hydrogen and in case where mercury is also present. In the former, exposures of the order of one hour sufficed (*cf.* I), whereas four to five hours were required for obtaining spectra of the same intensity in the latter case. It has been mentioned already that the atomic spectrum is expected to be relatively enhanced with respect to the molecular spectrum on account of the presence of Mercury vapour. There is the possibility, therefore, that the general background between $\lambda 3600$-$5000 Å$ (approximately), in which region the lines of the Balmer series lie, may get accentuated in intensity because of the strong atomic lines. In order to avoid confusing the issues, we shall consider the intensity distribution of the continuous spectrum from about $\lambda 3600 Å$ towards the short wavelength side (up to $\lambda 2300 Å$). For the sake of convenience the relative intensity distributions in the various spectra are compared with that obtained in the Geissler tube. Figures. 2, 3, 4 give the micro-photometer curves obtained with excitation by canal rays of energy 2, 3, 4, 6, 8, 10 kV. (*cf.* Pl. 8 and 4). The pressures used in these experiments were of the order of 10^{-2} cms. of Hg and less. The effect of Mercury vapour apparently begins to count only for the higher operating voltages of the order of 4 kV. or more. The variation in the relative intensity distribution curves for the low voltages (*viz.*, 2 and 3 kV.) is insignificant and the general shape of the curves approximates to that obtained in the Geissler tube. It has been shown in (I) that the intensity distribution curves in the case of the Geissler tube spectrum and the canal ray spectra are sensibly the same except for a small variation in the intensity of the region in the neighbourhood of $\lambda 2500 Å$. Spectra obtained with canal rays of energy of 4 kV. or more in the presence of Mercury vapour show a markedly more rapid fall in the intensity towards the short wavelength region. This departure from the usual distribution does not, however, show any regular dependence on the energy of the canal rays. Thus with 6 kV. energy canal rays the fall is more rapid than with 4 kV. energy. It is more rapid with 10 kV. than with 8 kV.; there is no difference on the other hand in the course of the intensity distribution obtained with canal rays of energy 4 and 8 kV.

In general, therefore, we can say that the presence of Mercury vapour affects appreciably the relative intensity distribution of the continuous spectrum, the effect being more pronounced at the higher voltages than at the lower ones. This has the net effect of bringing about an apparent variation in the intensity distribution of the continuum with the energy of the exciting canal rays. That there is no such effect has been shown in (I). It must be pointed out that the Mercury vapour being present only in traces in the discharge tube, it was not possible to control the quantity of the vapour present and thus maintain it constant. That it

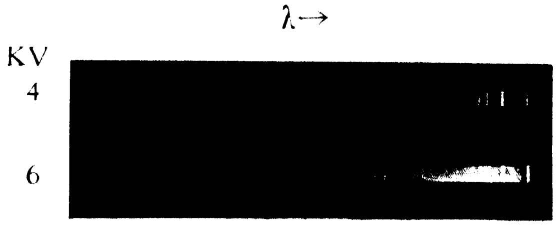

Fig. 1. (Pl. 4)

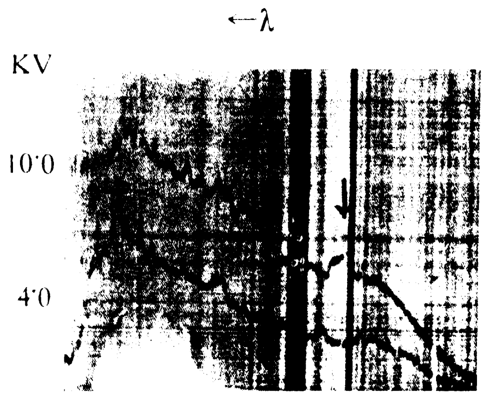

Fig. 2. (Pl. 4)

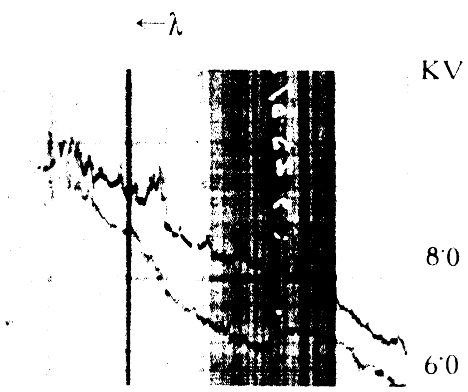

Fig. 3. (Pl. 4)

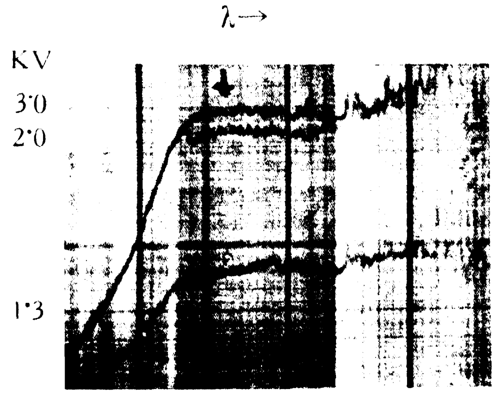

Fig. 4. (Pl. 8)

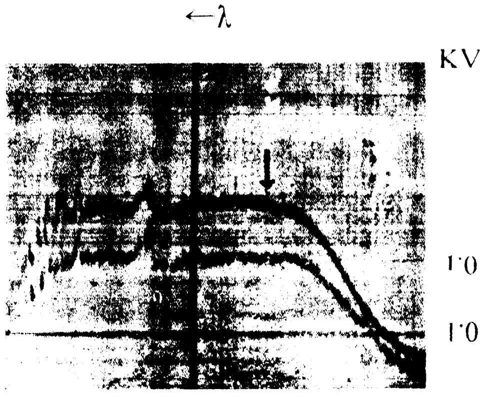

Fig. 5. (Pl. 6)

Figs. 1-4 Give the Spectra excited by Canal Rays of different energies.

Fig. 5 Gives the spectrum obtained in the Geissler tube.

The arrow in the figures indicates the position of the mercury line λ 2537Å was present in appreciable amounts throughout the course of the experiment is shown by the continued presence of the λ2537Å line with great intensity. It is likely that the amount of Mercury present in the vapour phase varied from experiment to experiment, for we naturally expect this amount to be relatively more at the lower pressures than at the higher ones.

It appears difficult to suggest a hypothesis for the explanation of the effects observed on account of the extremely large number of possibilities. Mercury in the molecular form, for example, possesses a large number of continua of its own (Finkelnburg[8]). Added to this, we have the possibility of the formation of the HgH molecules and a subsequent emission of its band spectrum (Jazewski[9]). It may be that the effects observed are of the type reported by Smith.[6] The possibility of collisions of second kind has already been pointed out. The experiments reported here make it clear that the presence of Mercury vapour is quite likely to vitiate results obtained on the intensity distribution of the continuum excited by the canal rays. The discrepancies in the results obtained by different workers may, therefore, well be due to such effects.

In the end, I offer my grateful thanks to Dr. S. S. Joshi for giving me the facilities for work and constant encouragement and to Dr. Asundi, with whose guidance the above work was carried out. To Dr. Ishaq, Chairman, Physics Department, Muslim University of Aligarh, I am indebted for facilities for the micro photometer work.

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